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(71) Applicant(s)
Teledyne Industries Inc

(Incorporated in USA - California)

1901 Avenue of the Stars, Los Angeles,
State of California 90067, United States of America

(72) Inventor(s)
Edwin I Bernard

(74) Agent and/or Address for Service
Potts, Kerr & Co
15 Hamilton Square, BIRKENHEAD, Merseyside,
L41 6BR, United Kingdom

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(56) Documents Cited
GB 2206444 A US 5226723 A US 5173810 A
US 5130761 A US 5043716 A US 4727457 A

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(54) Optical lens system for light emitting diodes

(57) An assembly 20 for enhancing the light produced by a light emitting diode which utilizes a bare diode 21 positioned on a substrate 22 having a flat surface 23, covered by a lens 27 which is adapted to focus the rays emanating from the light emitting diode in a manner to intensify the light produced. The surface of the substrate is coated 24 in a manner to reflect light emanating from the diode and to redirect it toward the intensifying lens. The lens may be a total internal reflection lens. Such a light emitting diode assembly has been found to produce light which may be approximately twenty-five times as intense as the light produced from a normal light emitting diode module as seen by the human eye.

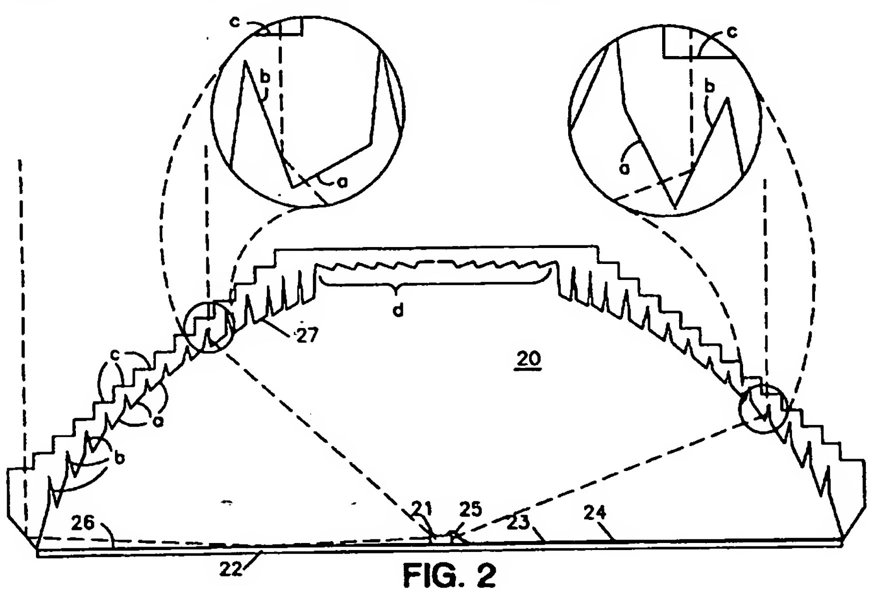

FIG. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Prior Art

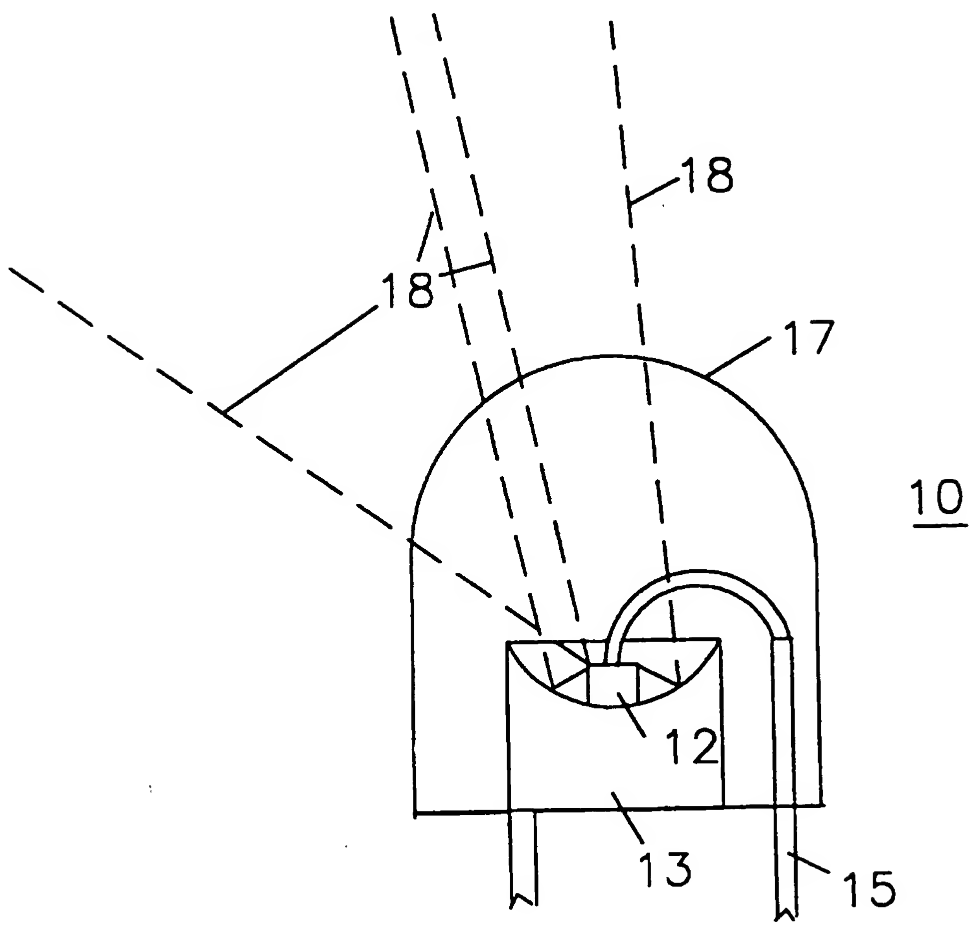


FIG. 1

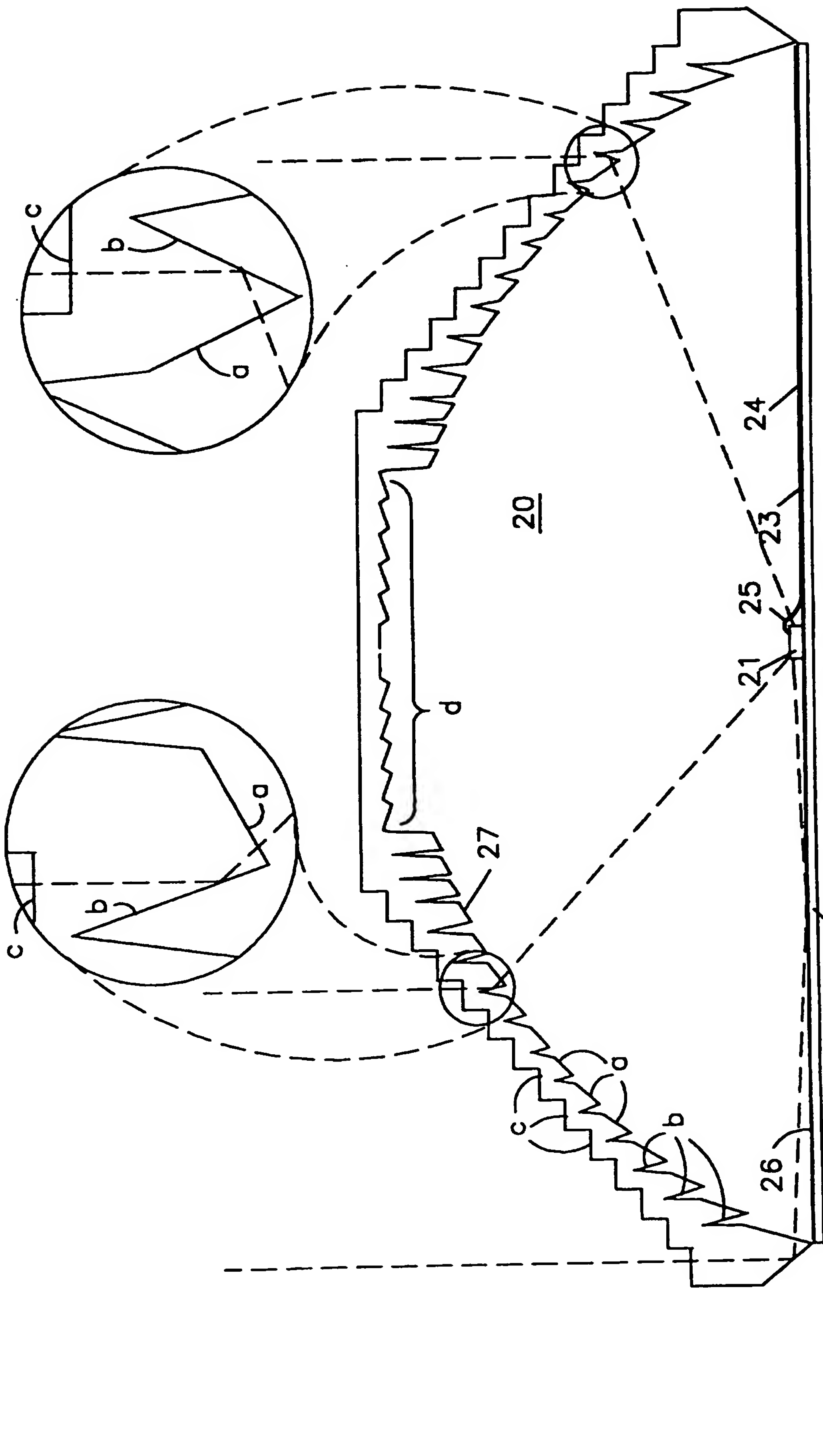


FIG. 2

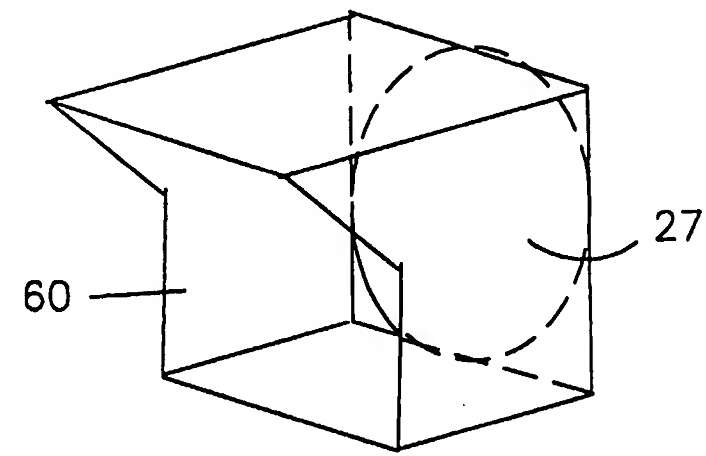


FIG. 6

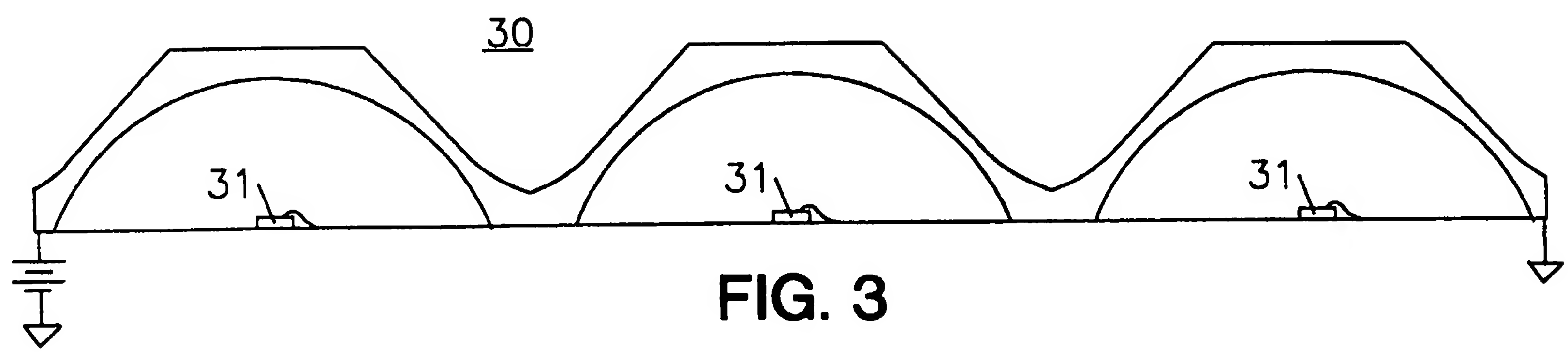
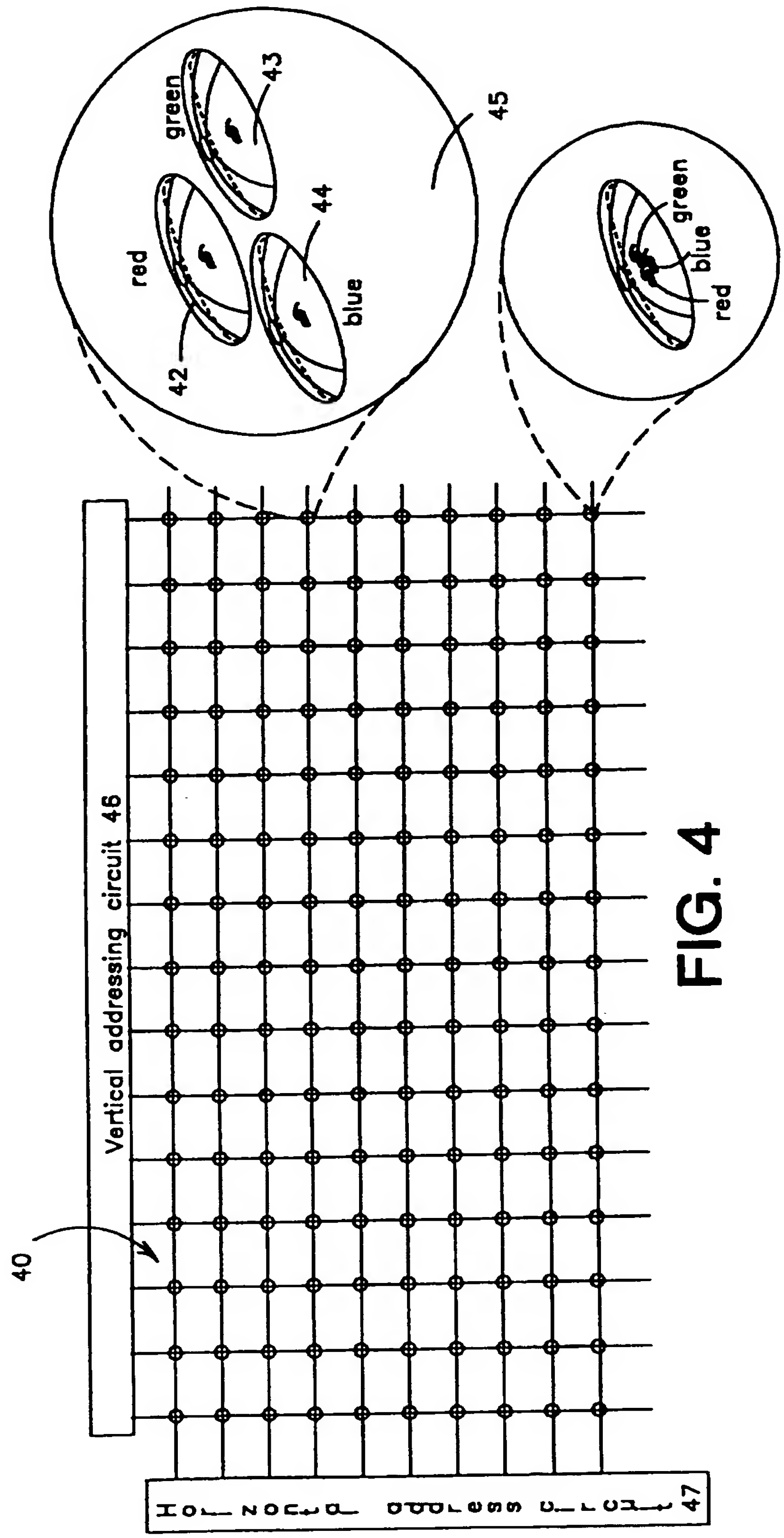


FIG. 3



43
green
45
44
red
blue
42
green
blue
red
Vertical addressing circuit 46
40
47

FIG. 4

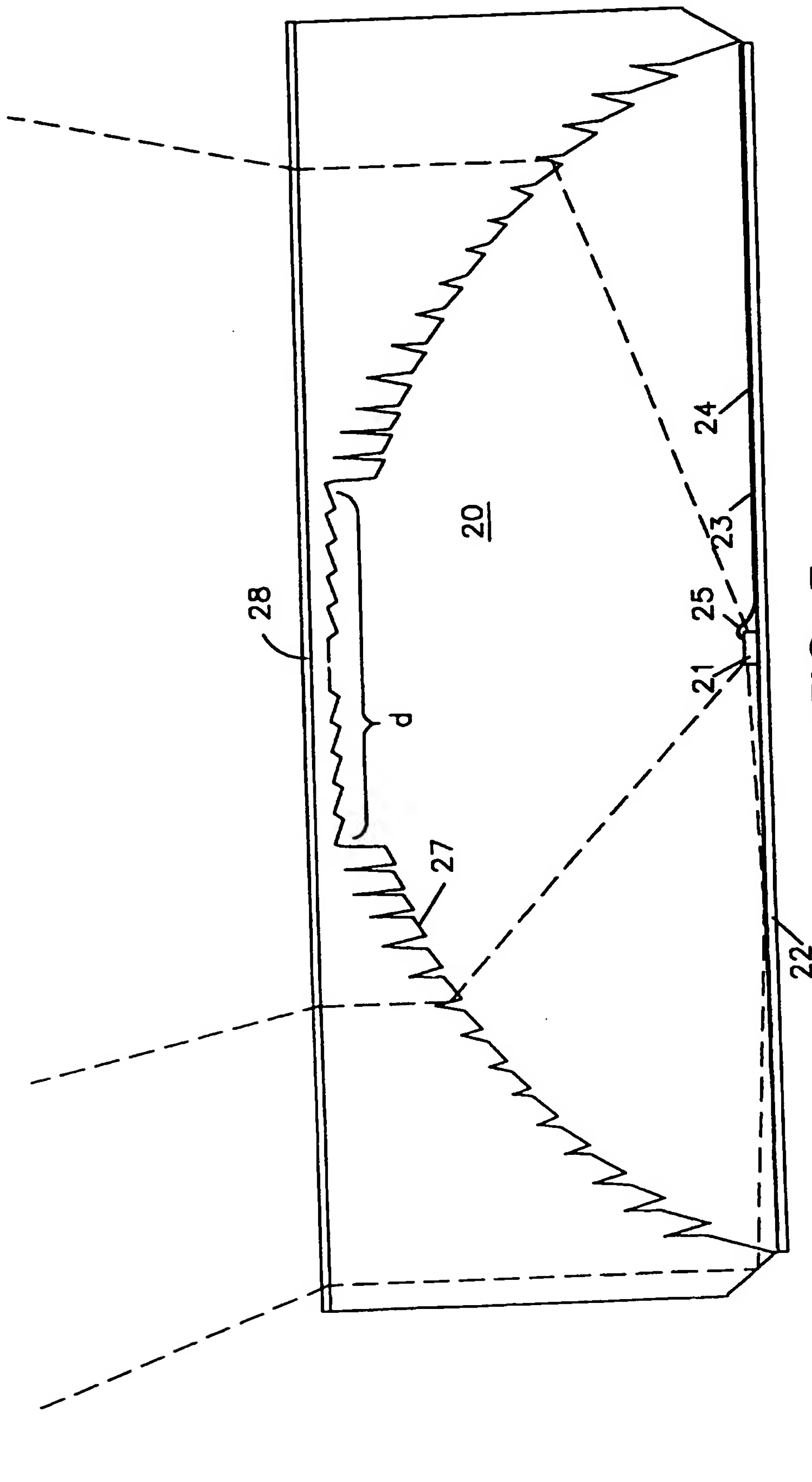


FIG. 5

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OPTICAL LENS SYSTEM FOR LIGHT EMITTING DIODES

BACKGROUND OF THE INVENTION

Field Of The Invention

This invention relates to light emitting diodes and, more particularly, to optical lens systems for producing high intensity output from light emitting diodes.

History Of The Prior Art

Light emitting diodes (LEDs) have been produced for a number of years and have been used for many purposes. Light emitting diodes have characteristics that are especially useful in many situations. They require a small amount of energy and therefore may use less expensive wiring. They respond very rapidly compared to incandescent lamps. They are less easily damaged than are other forms of lighting and do not burn out in normal use as do some other forms of lighting such as incandescent bulbs. They require much less space than do most other types of lighting.

A major problem which light emitting diodes do have is that the intensity of their output is small compared to other forms of lighting. For this reason they have found the greatest use in conditions in which the ambient lighting is subdued. In general, they are not used to provide illumination for other objects but only to display a color which may indicate a particular condition exists. One of the primary purposes have been to provide displays of various sorts. For example, light emitting diodes are used to define digital outputs provided by calculators.

Other than their low intensity output, light emitting diodes are perfectly adapted to a number of purposes for which other more expensive forms of lighting are presently used. In order to provide intensities sufficient to meet these purposes, large pluralities of light emitting diodes have been clustered together. This clustering increases their intensity but also increases their expense to a point where they are not competitive with other products. Recently, light emitting diodes have been used to produced center high mounted signal lights (CHMSL) for automobiles. A large serially connected plurality of from fifteen to twenty of these modules of light emitting diodes provides a chain of lights sufficient to act as a form of tail light and to provide a warning to drivers following closely. However, this appears to be the extent of present use of such diodes for purposes which require any substantial intensity.

It is desirable to provide new light emitting diode assemblies which allow the use of light emitting diodes in situations presently restricted to lighting requiring much greater intensities.

Summary Of The Invention

It is, therefore, an object of the present invention to provide apparatus and methods for providing new light emitting diode assemblies adapted to provide at least an order of brightness greater than that presently available from light emitting diodes.

It is another object of the present invention to provide assemblies which allow the use of light emitting diodes in situations presently restricted to other much more expensive, less efficient, and less reliable forms of lighting.

These and other objects of the present invention are realized in an assembly which utilizes a bare light emitting diode positioned on a substrate of essentially flat material covered by a lens which is adapted to focus the rays emanating from the light emitting diode in a manner to intensify the light produced. The surface of the substrate is coated in a manner to reflect light emanating from the diode toward the substrate and to redirect it toward the intensifying lens. Such a light emitting diode assembly has been found to produce a light which may be approximately twenty-five times as intense as the light produced from a normal light emitting diode module as seen by the human eye and which may be used for a multiplicity of purposes heretofore restricted to other more expensive and less reliable forms of lighting.

These and other objects and features of the invention will be better understood by reference to the detailed description which follows taken together with the drawings in which like elements are referred to by like designations throughout the several views.

Brief Description Of The Drawings

Figure 1 is a block diagram of a light emitting diode assembly designed in accordance with the prior art.

Figure 2 is a light emitting diode assembly designed in accordance with the present invention.

Figure 3 is another light emitting diode assembly designed in accordance with the present invention.

Figure 4 is yet another light emitting diode assembly designed in accordance with the present invention.

Figure 5 is another light emitting diode assembly designed in accordance with the present invention.

Figure 6 illustrates an arrangement for mounting lens assemblies designed in accordance with the present invention.

Detailed Description

Referring now to Figure 1, there is illustrated a light emitting diode assembly 10 typically found in the prior art. The assembly 10 includes a die 12 of semiconductor material of which the light emitting diodes are constructed. The material of such a die 12 may be gallium phosphide which produces a yellow-green light, aluminum gallium arsenide which produces a red light, indium aluminum gallium phosphide which produces a yellow light, silicon carbide or gallium nitride both of which produce blue light, or other similarly known materials. The dice are manufactured in large wafers in a manner well known to those skilled in the art to provide the light generating properties of light emitting diodes. The wafers are separated into the multiplicity of individual dice.

The die 12 of Figure 1 is typically mounted in a metallic parabolic focusing arrangement 13 which aids in accumulating as much of the light emitted by the diode as is possible. The die 12 typically has metallic bonding pads on its upper and lower surfaces for providing anode and cathode connections for the diode. The cathode bonding pad of the die 12 is typically bonded to the surface of the metallic focusing

arrangement 13 while the anode bonding pad of the die 12 may be wire bonded to a metal lead frame 15. The entire assembly is enclosed in a clear epoxy 17 from which connections to the focusing arrangement and the lead frame project. When a sufficient potential (e.g., 1.5 to 2.5 volts) is furnished between the metal lead frame 15 and the focusing arrangement 13 to conduct current in a forward direction through the diode, light is generated by the diode. The light from the diode is focused by the parabolic focusing arrangement 13 and shines in a generally direct path out of the top of the epoxy covering 17.

It should be noted that the light focusing arrangement 13 is specifically designed to collect as much as possible of the light generated by the diode. The arrangement 13 is, however, an imperfect light collector; and, as will be noted from the paths of the light rays 18 shown in Figure 1, some substantial portion of this light tends to be lost to the sides of the diode. Typically, the amount of light produced is sufficient to be used as an indicator light for electronic equipment or the like but is not sufficient to be used for lighting exterior objects. Consequently, such assemblies tend to be used for indoor displays. Recently, however, strings of these assemblies connected in series have been used as the center high mounted signal lights on certain automobiles. The strings of light assemblies are useful where they are to be viewed relatively closely but cannot be used where more intense lighting is required.

One recent use for light emitting diodes has been in arrangements for producing color pixels for large displays which are to be viewed at relatively long distance, such as across a room or a playing field. To provide a sufficient intensity for this purpose, a large number of

packaged light emitting diodes have been clustered together in a tube mounted to a printed circuit board with drive electronics on the back of the board. In some cases, a number of diodes of red, green, and blue are clustered in a single tube; and each diode is provided with individual addressing means. For example, four red diodes, seven green diodes, and nine blue diodes clustered in a tube may be used to select any of a number of colors depending on the intensity of each of the three colors enabled at once. The tube of clustered diodes provides what amounts to a single pixel on a cathode ray tube. Alternatively, three such tubes each containing a cluster of diodes of a single color (red, green or blue diodes) may be positioned adjacent one another; then by selecting the amounts of red, green, and blue through individual addressing means for each of the colors, a similar wide selection of individual colors may be produced with the three tubes together representing a single pixel. With a large number of these individual tubes mounted to a plurality of circuit boards, a large display of pixels may be produced for viewing. As will be understood, such a display is very expensive. However, it is less expensive than competitive displays in which each pixel is represented by three individual cathode ray tubes each of a different color.

Attempts have been made to utilize light gathering lenses with the modular diode assemblies such as the assembly 10 shown in Figure 1. However, light gathering lenses have not proven useful with these diode modules because a substantial portion of the light from the diode is already focused into collimated rays by the parabolic form of the focusing arrangement 13 so that very little additional light is gathered from these rays; and because rays which are not collimated are so defocused by

refractive action of the epoxy covering 17 that they cannot be properly refocused by a light gathering lens. Consequently, the increase in the perceived intensity of the light produced is relatively small.

The present invention provides an assembly which allows light emitting diodes to be utilized in a great number of situations which have previously been restricted to clusters of very large numbers of light emitting diodes or to much more intense lighting sources such as incandescent lamps, cathode ray tubes, and similar lighting sources.

The present invention utilizes a new assembly 20 illustrated in Figure 2 in which a bare light emitting diode 21 is mounted to a substrate 22 in the middle of an essentially flat surface 23. The surface 23 is coated in a circular pattern with a reflective conductive material 24 such as tin or nickel to a diameter which preferably is about ten times the length of the diode. The diode is centered and mounted on the reflective coating and connected to trace electrodes 25 and 26 on the surface of the substrate, and a light gathering lens 27 is centered to form an inverted bowl over the diode. The light from the bare diode 21 is dispersed in all directions directly from the diode. The lens 27 collects the light from the diode 21 and from the reflective surface 24 to provide a very high intensity output. Such an output as perceived by the human eye is approximately twenty-five times the intensity of the output provided by light emitting diodes utilized with the typical assemblies of the prior art.

In order to produce this result, it has been found that light gathering lenses such as those described in U. S. patent 4,337,759, entitled <u>Radiant Energy Concentration By Optical Total Internal Reflection</u>,

Popovich et al, issued July 6, 1982, provide excellent results. These lenses, often referred to as total internal reflection (TIR) lenses, are designed to direct light from an external source towards a target object although the patent describes utilizing the lenses to direct light from the target source in the manner of the present invention. When associated with a bare diode placed directly on top of the reflective surface, rather than an encapsulated diode, the light gathering properties of the lens are found to be extremely useful. This occurs because, as contrasted to the encapsulated diode which produces rays which are essentially collimated upward from the diode as illustrated in Figure 1 or diffused by refraction through the epoxy covering, the rays from a bare diode are transmitted in all directions from the diode and are thus gathered by the lens 27 to produce a high intensity light.

The lens 27 is designed to provide both reflecting and refracting surfaces to each ray emanating from a light source such that the paths of all of the rays are concentrated. For example, the blown-up portions of Figure 2 illustrate the paths of two different rays from a diode 21. As may be seen, at each possible angle from the diode 21 and the reflecting surface 24, a first lens surface (a) is provided at essentially a right angle to the impinging ray so that refraction of the ray does not occur as it enters the lens material, while a second lens surface (b) is provided for mirroring the and directing the rays originating at the diode upwardly through a third lens surface (c) again at essentially a right angle to the impinging ray so that refraction of the ray does not occur. Typically, this produces a very intense collimated light. Directly above the diode in area (d) the lens 27 is a Fresnel lens which concentrates and redirects the path of the

rays at a small angle upwardly by refraction alone. It will be understood that in order to be able to utilize the lens 27 in this manner, the diode 21 must be very accurately positioned with respect to the lens 27.

By varying the angles of the internal reflecting or refracting surfaces of the lens 27, different angles of dispersion may be realized. Thus, a single diode may be caused to produce an intense collimated beam which may replace a very large plurality of individual diodes. Alternatively, the diode may be made to produce a dispersed beam of any selected angle which may be made to fit the purpose to which the diode is to be put.

A preferred manner of dispersing a beam produced by the lens assembly utilizes a dispersing surface such as a holographic diffuser or prismatic lens 28 positioned at the exit surface of the lens 27 as is illustrated in Figure 5 designed to disperse light in a selected pattern. Such lenses produce easily controllable angles of dispersion, and may be easily manufactured as a level upper surface to the lens 27 to replace the exit surfaces shown in Figure 2, for example. Such a lens 28 disperses the rays in the desired manner once the light has been collimated by the internal surfaces of the TIR lens 27. This allows the light to be collected to provide the desired intensity and then dispersed in the manner chosen. Once the light has been collimated, a dispersing surface such as a sandblasted surface will produce a much greater light intensity than a normal light emitting diode module.

Figure 3 is another arrangement 30 in accordance with the present invention. In the arrangement 30 a plurality of light emitting diodes are grouped on a single substrate. Each of the light emitting diodes 21 has

an individual light gathering lens 37 placed over it. This grouping of light emitting diodes allowed a very much more intense output to be produced by the assembly. Such light emitting diodes may conveniently be provided in assemblies using the same colored red diodes and may function, for example, as the main tail lights of automobiles. These assemblies are much lighter than incandescent light assemblies, much less fragile, require less energy, respond more quickly to braking, and produce a brighter output. The parts used to produce these assemblies are less costly. Plastic lenses may be easily molded in shapes to produce the light gathering lenses and may, in fact, be molded into the surfaces of a tail light assembly or the informational portion of a dashboard.

Figure 4 is another example of an assembly 40 of light emitting diodes in accordance with the present invention. The assembly 40 includes a plurality of light emitting diodes of different colors. For example, a red diode 42, a green diode 43, and a blue diode 44 may be grouped on a substrate 45 in the manner explained above with each diode having its own separate lens as shown in the expanded view at the upper right. Alternatively, the three colored diodes may be grouped under a single lens as is illustrated in the expanded view at the lower right in Figure 4. If the cathodes of the diodes 42-44 are joined together to a potential while the anodes are separated so that another enabling potential may be switched to selected ones of the diodes, then desired color outputs may be produced by the assembly. Connected to the diodes 42-44 are separate addressing circuits 46 and 47 of a type well known to the prior art. The assembly 45 may be made to produce an output much like that of a single pixel in a cathode ray tube. By grouping similar assemblies

together, color displays may be produced which are capable of presenting from one to ten lines per inch at the present state of the art. This is especially useful for producing color displays much like color television or computer displays which may be viewed from a distance such as across a room or a playing field. Such displays produce sufficient intensity, in fact, that they may conveniently and inexpensively produce displays such as those used at ball parks.

Figure 6 illustrates an arrangement for mounting lens assemblies designed in accordance with the present invention in order to enhance the apparent intensity of the light provided. If a diode lens assembly 27 is to be utilized in daylight or other circumstance involving high ambient light conditions, it may be arranged with a hood 60 adapted to shield the actual diode assembly from the ambient light and thereby heighten the contrast between the light produced by the assembly and its immediate surroundings. A single diode assembly or a plurality of diodes in an array or similar pattern may be so mounted.

In order to manufacture displays such as those of the present invention, the following process may be followed. First an appropriate number of dice of the appropriate colors for the light emitting diodes to be produced are selected and prepared for bonding by having bonding pads attached usually to the top and bottom of each die. Then a substrate such as a printed wiring board is prepared with the appropriate metallic traces (usually nickel plated copper) suitable for the types of connections to be accomplished to the anode and cathode terminals of each die. If the dice are to be connected in series, then each of the cathode and anode terminals must be separately connected to individual conductive traces.

If the dice are to be connected in parallel, all of the cathode (or anode, depending on diode design) terminals may be joined to a single conductor. In such a case, the reflective surface may in fact form such a conductor. Then coatings which provide the circular reflective areas are plated or evaporated onto the substrate in appropriate dimensions to provide the reflective surfaces for each of the diodes. Where a plurality of diodes are to be assembled on a single substrate, the individual reflective coatings need not be circular, rather a reflective coating may cover most of an entire surface. Next, the dies are individually selected by a placing machine and positioned on the substrate where they are bonded to the substrate at the lower bonding terminals of each of the dice. The upper terminals are then wire bonded to the appropriate conductors to complete the connections. Finally, the lenses are placed in position over the diodes. In some cases, the substrate with the bonded dice may, in fact, be placed in a correct position with respect to the lenses. Ultimately, the appropriate electrical connections are made to the conductors joining to the cathodes and anodes of the diodes, addressing circuitry is provided if necessary to the use being made, and the assemblies are arranged in circuit in a manner well known to the prior art.

One technique by which the reflecting surfaces of the assemblies may be prepared when a large surface is to be coated is by a technique called hot air leveling. This technique is well know and is typically used for applying thin coats of tin/lead solder to printed wiring boards. Such a technique is able to provide very accurate layers of reflective coating which may be utilized in the present invention. A description of this

process in detail is provided by a technical paper entitled Hot Air Leveling- Surface Mount Pads and Assembly Process, IPC-TP-928, Goodell and Banks, presented October 7-12, 1990, and published by the Institute for Interconnecting and Packaging Electronic Circuits, Lincolnwood, Illinois.

In brief, the process includes preclean, preheat, flux, solder, airknives, cooldown, and postclean steps. The preclean step may employ a microetch to remove essentially one micron of copper and to ensure that organic contaminants are reduced sufficiently for soldering, a water rinse, and hot air dry sub-steps. The preheat step typically applies infrared preheat to the top and bottom of the substrate at a typical exit temperature of 130 to 160 degrees centigrade at the board surface. Flux is applied using flooded top and bottom nap rollers with a typical solder leveling flux. The process may be practiced with either a horizontal or a vertical soldering step. The horizontal soldering section contains eutectic Sn/Pb solder at about 260° C. A glycol oil compatible to the flux is used to limit dross formation on the solder. Boards are propelled through the solder by tapered rollers so that they are exposed for a dwell time of two seconds. When the boards emerge from the solder, they are immediately exposed to hot air knives at high temperature. The airknives are mounted at the top and bottom of the board approximately one degree from vertical and offset by 0.25 mm. and furnish air at a temperature of between 200-220° C. The airknife-to-board separation is typically 0.38-0.76 mm. The cooldown step uses an airbed and a muffin fan unit. The postclean step utilizes sub-steps including a detergent wash, a high pressure hot water rinse, and a hot air dry.

Although the present invention has been described in terms of a preferred embodiment, it will be appreciated that various modifications and alterations might be made by those skilled in the art without departing from the spirit and scope of the invention. The invention should therefore be measured in terms of the claims which follow.

CLAIMS

1. An assembly for providing a directed light from a light emitting diode comprising:

a substrate of essentially flat material,

first and second conductors placed on the substrate,

a bare light emitting diode positioned on a surface of the substrate and joined to the conductors,

a reflective surface on the surface of the substrate which the diode is positioned, and

a total internal reflecting (TIR) lens positioned over the diode to focus the light emanating from the light emitting diode in a manner to intensify the light produced by the diode and the light reflected by the surface.

2. An assembly as claimed in Claim 1 in which the TIR lens is shaped to disperse light from the bare diode.

Claim 3. An assembly as claimed in Claim 1 in which a surface of the TIR lens is designed to disperse light in a selected pattern.

4. An assembly as claimed in Claim 3 in which the surface of the TIR lens designed to disperse light is designed as a holographic diffuser.

5. An assembly as claimed in Claim 3 in which the surface of the TIR lens designed to disperse light is designed as a prismatic lens.

6. An assembly as claimed in Claim 1 including a plurality of bare diodes, and a plurality of TIR lenses, one such lens positioned over each such diode.

7. An assembly as claimed in Claim 6 in which the diodes and TIR lenses are arranged in groups of different colors adapted to produce the color white when all diodes of a group are turned on.

8. An assembly as claimed in Claim 7 further including addressing circuitry for selectively turning on individual diodes in each of such groups.

Claim 9. An assembly as claimed in Claim 1 further comprising a hood placed over the assembly for shielding the assembly to increase contrast between light from the TIR lens and a surrounding area.

10. An assembly for providing light from light emitting diodes comprising:

a substrate having an essentially flat surface,

conductors placed on the substrate for conducting current to and from light emitting diodes,

a bare light emitting diode positioned on the flat surface of the substrate and joined to the conductors,

a reflective coating on the flat surface of the substrate immediately under the diode and extending therefrom, and

a light gathering lens positioned over the diode to focus the light emanating from the light emitting diode in a manner to intensify the light produced by the diode and the light reflected by the surface.

11. An assembly as claimed in Claim 10 in which the reflective coating on the flat surface of the substrate comprises a hot air leveled coating.

12. An assembly as claimed in Claim 11 in which the coating comprises tin/lead solder.

Claim 13. An assembly as claimed in Claim 10 in which the reflective coating on the flat surface of the substrate is approximately ten times the length of the bare diode.

14. An assembly as claimed in Claim 10 in which the light gathering lens is a total internal reflecting (TIR) lens.

Claim 15. An assembly as claimed in Claim 14 in which the TIR lens is shaped to disperse light from the base diode.

16. An assembly as claimed in Claim 14 in which an outer surface of the TIR lens is designed to disperse light in a selected pattern.

17. An assembly as claimed in Claim 10 further comprising

a plurality of bare light emitting diodes positioned on the flat surface of the substrate and joined to the conductors, and

a plurality of light gathering lenses positioned over the diodes.

18. An assembly as claimed in Claim 17 in which the bare light emitting diodes are clustered in groups designed to provide red, green, and blue light; and further comprising addressing circuitry for selectively enabling diodes to produce different colored light from the individual groups.

19. An assembly as claimed in Claim 10 in which the light gathering lens is built into a cover for the assembly.

20. An assembly as claimed in Claim 10 which further comprises a hood for shielding the assembly from ambient light.

The Patent Office

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Application N : GB 9523157.7
Claims searched: 1-20

Examiner: Miss J.E.Evans
Date of search: 8 February 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H1K (KQAME, KEAX, KEE)

Int Cl (Ed.6): H01L 33/00

Other: W.P.I.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2206444A	(Cheng) see abstract & figs 1,2,4,6,8,10.	10,17,19
X	US5226723	(Chen) see figs 1-3 and col. 1, lines 43-58	10,17
X	US5173810	(Yamakawa) see figs 1,4 & col.3, lines 45-58	1,10,14
X	US5130761	(Tanaka) see abstract	10,19
X	US5043716	(Latz) see abstract	10,17
X	US4727457	(Thillays) see fig 1 & abstract	10

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		